The Machinery for Economic Planning: IV. The Ministry of Technology

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My task is to describe the work of the Ministry of Technology and how it fits into national economic planning. I intend to approach it in two stages: first, to attempt a brief historical review of government interest in the application of science to industry and then to describe the various weapons at the disposal of the Government nowadays and how they are deployed.

HISTORICAL

The literature of technology is a formidable affair. I have not attempted to discover the earliest point at which the State first expressed a practical interest. I am sure it would have been a fascinating study. Knowing the pre-occupation of sinful man with money and violence, I would expect to find interest first attracted by the coinage or by military weapons. I might perhaps have discovered that after the Battle of Bannockburn Edward II created a fund of 100 groats dedicated to the improvement of the English pike.

I doubt if the lack of early history matters to my purpose. I must, however, record one important landmark in the shape of the formation of the Royal Observatory in 1675. This was nothing if not a practical affair. Navigation being vital to a maritime nation, the Royal Observatory was created for the express purpose of improving navigational technology.

By the middle of the last century we can detect a gently rising curve of government interest. In the early stages the Government rarely took the initiative. Usually, the scientists and industrialists were knocking on the door.

The Great Exhibition of 1851 marked the high water mark of British industrial pre-eminence. Twenty years later a wind of a different character was blowing. A marked decline in our position had become apparent, connected by many with the lack of systematic technological education.

In his book *Technology and the Academics*, Sir Eric Ashby remarks:

'Before the 1870's there was neither an adequate supply of pupils trained in science from schools nor an adequate demand from industrialists for graduates. Training in technology was through apprenticeship, on the job; and any formal training in colleges was regarded with suspicion as likely to lead to the disclosure of know-how and trade secrets. There was no lack of warning against the inadequacy of this profession. Even the circumspect Royal Commissioners of the University of Cambridge suggested that the basic principles of engineering should be taught there. But warnings were not enough; a much more powerful impact was needed to overcome public inertia towards technological education. That impact was provided by the International Exhibition held in Paris in 1867. In 1851 British products had carried away most of the prizes. In 1867 British products received a bare dozen awards. No longer was there a re-assurance of British industrial supremacy. Instead, there was alarming evidence that Britain had made little progress in the peaceful arts of industry since 1851 and that continental countries had become very serious competitors'.[1]

In 1868, following much prodding, Parliament appointed a Select Committee on the Provision for giving instruction in Theoretical and Applied Science to the Industrial Classes. Its report contains many shrewd remarks. I may perhaps quote one of them:

'More generally, the training of capitalists and the managers of their classes has been that of the higher secondary schools followed in rare instances by a course of more or less systematic scientific instruction. The scientific courses of Oxford have been too recently instituted and have hitherto been devoted entirely to pure science to have had any appreciable influence on the scientific instruction of this class; besides which the feeling exists, to which expression was given by Mr.Chance, the eminent manufacturer of Smethwick, himself a man of great scientific attainments and a distinguished member of the University of Cambridge, that, however suitable Universities may be or become for the training of Professors of Science of the highest class, the habits at present acquired there by the sons of wealthy men are not conducive to the successful prosecution of an industrial career'.

This report is one of the great landmarks in the history of technological education in this country. Another technological landmark, thirty years later, was the formation of the National Physical Laboratory at the turn of the century. The impulse leading to this can be found in public concern at the development of German industry after the Franco-German war, a development founded on a close alliance between German science and German industry and symbolized in 1887 by the creation of the famous Charlottenburg Physical Institute with Helmholtz as Director and Siemens as one of its patrons. By the end of the century, largely as the result of this alliance, Germany was moving towards the industrial supremacy of

Europe. In 1897 a rising tide of concern in Britain found expression in the appointment of a Committee of Enquiry under Lord Rayleigh. The Committee recommended that a government establishment should be created under the control of the Royal Society for the purpose of standardizing and verifying instruments; testing materials; and the determination of physical constants.

The Government's response to this report stopped well short of enthusiasm. They granted £12,000 for buildings and an annual sum of £4,000 for five years. These amounts can be contrasted with £195,000 and an annual grant of £15,000 provided by the German Government for the Charlottenburg Institute and with £115,000 for buildings and an annual grant of £19,000 provided by the American Government for the Bureau of Standards at about the same period.

In opening the N.P.L. the Prince of Wales (later King George V) used some remarkable and prescient words. He said:

> 'I believe that in the National Physical Laboratory we have the first instance of the State taking part in scientific research. The object of the scheme is, I understand, to bring scientific knowledge to bear practically upon our everyday industrial and commercial life, to break down the barrier between theory and practice, and to effect a union between science and commerce. This afternoon's ceremony is not merely a meeting of the representatives of an ancient world-renowned scientific society for the purpose of taking over a new theatre of investigation and research. Is it not more than this? Does it not show in a very practical way that the nation is beginning to recognize that if its commercial supremacy is to be maintained, greater facilities must be given for furthering the application of science to commerce and industry?'

The biggest single advance in the Government's interest in technology occurred under the pressures of the First World War when the Department of Scientific and Industrial Research was created. In the words of a report prepared in 1916:

> 'The outbreak of war found us unable to produce at home many essential materials and articles. We were making less than a couple of dozen kinds of optical glass out of over a hundred made by our enemies. We could hardly make a tithe of the various dyestuffs needed for our textile industries with an annual output worth over £250 million a year. We were dependent on Germany for magnetos, for countless drugs and pharmaceutical preparations, even for the tungsten used by our great steelmakers and for the zinc smelted from the ores which our great Empire produced'.[2]

As the war proceeded the Government also became deeply concerned at the probable effect of these deficiencies in the post-war reconstruction when it seemed likely that British industry would find itself at a great disadvantage compared with its continental competitors.

The Government's response to the pressures was the formation of a

Committee of the Privy Council for Scientific and Industrial Research plus an Advisory Council and a Department (D.S.I.R.) to carry out the work.[8]

The first report of the Advisory Council is concerned almost exclusively with applying research to industry. In later years the work developed along four distinct lines:

(1) the creation of government laboratories;
(2) grants to universities in support of science and technology;
(3) grants to students for postgraduate work;
(4) grants to research associations.

The last development was peculiarly the brain child of the early work of the Advisory Council. They looked to the intense development of research in German industry and they took action which led, through government support, to the creation of a series of co-operative research associations in British industry.

Over the next fifty years there occurred a vast growth in government expenditure on civil research and development. By 1962, government expenditure on civil research and development, which for practical purposes stood at zero at the turn of the century, had reached a total of about £150m., made up as follows:

	£m.
Universities and Learned Societies	24.0
Department of Scientific and Industrial Research	21.4
Medical Research Council	6.0
Agricultural Research Council	6.5
Nature Conservancy	0.6
Development Fund	0.8
Ministry of Aviation	24.7
Agriculture Departments	4.6
Other Civil Departments	2.8
Admiralty – Observatories and Oceanography	1.0
Air Ministry – Meteorology and Aviation Medicine	1.0
Atomic Energy Authority (Civil Research and Development)	50.0
National Institute for Research in Nuclear Science	7.0
Space Research	1.2
Total	151.6

The total today would be in the neighbourhood of £200m.

The distribution of these funds was in the hands of a dozen separate authorities including the Treasury, the Lord President (operating through the Research Councils) the Ministry of Aviation, the Agricultural Departments, the Admiralty, the Air Ministry and the Atomic Energy Authority. At this stage the organization resembled a piece of sedimentary rock with the strata representing the various phases of government intervention.

The Trend Committee[4] was the first full scale review of civil research and development for fifty years. In the round, the Committee proposed:

(i) that activities in support of science in universities should be concentrated in two new Research Councils (later determined as the Science Research Council and the Natural Environment Research Council) to go alongside the Medical Research Council and the Agricultural Research Council;

(ii) that activities in support of research and development in industry should be concentrated under a new public authority to be called the Industrial Research Development Authority (I.R.D.A.).

These recommendations were for the most part adopted, though the present Government decided to create a Ministry of Technology to assume the functions proposed by I.R.D.A. and to take responsibility for a special national effort to bring technology and new processes into British industry. Specifically, the responsibilities of the Ministry of Technology were defined as follows:

> 'The Minister of Technology has the general responsibility of guiding and stimulating a major national effort to bring advanced technology and new processes into British industry. The methods employed will include an intensified use of the appropriate Research Stations and of the National Research Development Corporation, civil development contracts and studies to identify particular industries or parts of industries suitable for action. The Minister will consider what changes might be made in the arrangements for procurement financed by public funds in order to contribute to the aim of promoting technological advance. He will initiate studies of the status of the engineering profession.
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> 'All these tasks will be undertaken in close consultation with the other Departments concerned. As already announced, the Minister will be responsible for the Atomic Energy Authority and the National Research Development Corporation and will take over the elements of the Department of Scientific and Industrial Research headquarters which have been concerned with research and technical development in industry. The Ministry of Technology will in future be the sponsor department for the machine tools, electronics, telecommunications and computer industries. The Ministry will also establish close relations with the British Standards Institution and will support their work in the engineering field. The Science and Technology Bill now before Parliament proposes that the powers of the Atomic Energy Authority shall be extended to permit the Authority to undertake research and development outside the atomic field. Legislative action will also be taken to increase the powers and resources of the National Research Development Corporation'.[5]

'History is bunk' said Henry Ford and I feel under an obligation to explain why I have talked so long about the past.

My purpose was to emphasize:

(i) that government interest in technology is of long standing and that by the mid-60's it had acquired considerable momentum;
(ii) that government interest has been the response to external competition.

The fact is that government action or inaction can powerfully affect the ability of the nation to export. We have only to consider the effect of the United States Defence and Space programmes on the American machine tool and computer industries to realize the truth of this.

Government intervention, which has been building up over sixty years – here and abroad – has clearly come to stay. Of course, there are many different views about how this intervention should be organized. Other forms of organization than that which now exists would certainly be possible. This is an interesting theme, especially to your Institute. I cannot pursue this point tonight except to make one comment. In my experience, machinery of government problems usually involve principles which are at once:

(i) immutable; and
(ii) mutually inconsistent.

For example, in regard to technology the following principles apply:

(i) pure and applied science are indivisible;
(ii) education is a seamless robe stretching from the nursery school to post-doctorate teaching;
(iii) technology must not be separated from industry;
(iv) industry must not be separated from commercial policy.

If all these principles are applied to the full the result would be a piece of organization for which the appropriate adjective would be peculiar rather than practical. There is in fact no perfect solution. The aim must be rather to find a practical arrangement which produces the best balance of advantages over disadvantages.

One important feature of the present solution is, of course, that it puts the technological problems of industry under the direct interest of a Minister of Cabinet rank.

METHODS OF ATTACK

I now come to the various weapons in the government armoury for speeding the application of advanced technology and to discuss how they are applied.

(i) *Grants*

This is the time-honoured way by which the Government has supported applied science over the years. I have already mentioned the Research Associations. There are forty-eight of these and they vary widely in the

type of activity and the extent to which they are supported by the Government. The Government grant amounts to some £3.5m. a year.

The main innovations we have made to date are large increases in the grants to the Research Associations concerned with Production Engineering and the Scientific Instrument trade, these being closely connected, through process control and automation, with the objects which the Ministry of Technology exists to serve.

(ii) *Ministry of Technology Laboratories*

The Ministry of Technology is responsible for ten laboratories:

The National Physical Laboratory,
The National Engineering Laboratory,
The Laboratory of the Government Chemist,
Hydraulics Research Station,
Forest Products Research Laboratory,
Fire Research Station,
Building Research Station,
Torry Research Station (for the transport and storage of fish at sea and on land),
Warren Spring Laboratory (chemical, engineering, mineral processing and air pollution),
Water Pollution Research Laboratory.

I cannot discuss all their activities though I should like to do so. I would like to tell you, for example, how the Government Chemist deals with the effects of crop spraying and where the Water Pollution Laboratory has got on the effect of detergents. I cannot range as widely as this. Instead, I will pick out two examples of the work of the National Physical Laboratory.

The N.P.L. came into existence sixty years ago for purposes in which the improvement of physical standards played a very important part. This field is again growing in importance and I shall have more to say about this later. The exacting standards of accuracy now commonplace in engineering, the increasing reliance on automation controlled by instruments and the fact that, in so many fields, engineers have to respond to an international as opposed to a national environment alike demand a greater interest in standards. We thus look forward to a steadily rising curve of interest in this subject in the Laboratory.

My second illustration concerns their growing activities in regard to the effect of wind on structures. At the request of the consulting engineers, the N.P.L. has conducted a programme of tests into many new structures including the designs for the new suspension bridges over the Forth and the Severn. In the case of the Severn bridge, due to open next year, an entirely new design was tested in the N.P.L. wind tunnels and later adopted. I think you will be interested in the following details:

Bridge	*Date of completion*	*Main Span*	*Total Length*	*lbs. of steel per useful sq. ft. of area*
Severn	1966	3,240	5,240	85
Forth Road	1964	3,300	5,980	135
New York Narrows	1964	4,260	6,690	510
Humber	Planned	4,580	6,895	114

Thus, as the result of advances in design, the Severn bridge will use about one-sixth the weight of steel per unit of area as the American bridge.

The Laboratory is currently investigating the collapse of certain cooling towers at Ferrybridge.

(*iii*) *Other Government Laboratories*

Under the Science and Technology Act 1965, the Minister can ask the Atomic Energy Authority to undertake work in fields not connected with atomic power. Good use has already been made of this new power. The Authority has been given an important commission in regard to desalination, and important studies are proceeding in connexion with the biological use of centrifuges and the use of hydrostatic extrusion as a new method of forming metals.

The Ministry is also developing close links with certain research establishments in the defence sector with a view to making use of their great resources in the interests of civil development.

(*iv*) *The Regional Organization*

D.S.I.R. had offices in Scotland, Wales and the North East. We are now developing a regional organization to conform with the eight regional areas established under the National Plan. This organization will provide technical support for the Regional Councils and Boards and a local point of liaison between universities, government stations and industry. Most important of all, the regional offices will develop an advisory service for industry, particularly the smaller firms in industry whose resources do not permit a substantial research staff.* We hope that these smaller firms will be able to go to our local offices and through them obtain the advice they need. This could take the form of help from a university or from a government research station, or of assistance, e.g. from the Production Engineering Research Association. We believe that, over the years, these activities could have a profound effect on the efficiency of British industry.

*In this work the Ministry's regional offices will be supported by a network of Industrial Liaison Centres (some thirty-six in number at present, due to rise to seventy) which have been established in collaboration with the Department of Education and Science.

(*v*) *Relations with Industry*

The Ministry of Technology is critically dependent on the closeness of its contacts with industry. Special attention has been given to this point. The arrangements include:

(a) A strong Advisory Council.
(b) Representation on 'Little Neddies' and on the Steering Committee which directs their work.
(c) Contacts with Trade Associations and the C.B.I.
(d) Direct contact with individual firms in the particular industries in which we are specially interested.
(e) Contacts between industry and research stations.
(f) *Ad hoc* committees.
(g) Staff with recent industrial experience.

The Ministry of Technology is also the sponsor Department for four industries specially connected with modernization. They are: computers, electronics, telecommunications and machine tools. There is often doubt about the meaning of the word sponsorship. The system started in the last war when manufacturers needed permits from Whitehall for labour and materials. As a result, every industry was allotted to a particular Whitehall department. With the end of controls, sponsorship has come to mean much less but the words 'sponsor department' still signify to a particular industry its main point of contact with the government machine. It is, however, not an exclusive point of contact and firms are free to deal with departments other than their sponsor department for special needs.

The Ministry has, of course, made special studies of certain industries. These studies have revealed, among many other things, the high significance which attaches to structural problems. Sir Denning Pearson, in a recent lecture,[6] drew attention to the importance of establishing the minimum successful size of unit – a size which provides adequate facilities for design, development, test and marketing. He added that for many types of engineering product far too many of the production units are well below the minimum size which meets these criteria.

We have come across the same point which is a rather crucial one in view of the significance of engineering in the National Plan.

(*vi*) *The Computer Industry*

Computers can affect the economy in many ways. They can, of course, make calculations at fantastic speed. For example, the calculations for Professor Stone's computable model of national economy took 28 seconds on the Cambridge Atlas; they would otherwise have taken 60-man years.

Computers also control processes. But their significance for the economy is far wider than this. In time, as Sir Leon Bagrit pointed out in the 1964 Reith lectures, they will transform the face of society. I will give you three

indications:

(a) A computer system applied to a large industrial complex can produce a complete interlock between the shop floor and the administration, putting the manufacturing process virtually under automatic control and producing simultaneously all the control data needed by management.

(b) In medicine we are on the eve of a computer explosion. Computers can handle the formidable paper and inventory work for hospitals. But in addition they can also control major operations and give diagnostic services. They can also perform nursing services in, say, surgical cases in a large hospital. Data from a glove worn by the patient is fed into a central computer which watches over the patient and gives instant warning of significant change.

(c) My final example concerns the home. If, instead of a telephone pair, we used a coaxial cable it could be used not only for the telephone and to pipe in T.V. services but also to read the electricity and gas meters, to type out the bills and adjust the central records, thus making unnecessary a regiment of meter readers and clerks. It could also, of course, be the vehicle of computer services.

Of course, it can be argued that if we lack any of these skills we can import them and the associated hardware. And indeed the same argument can be used in almost any other technological scene. But I ask myself where this process would end. I do not personally believe that we can solve all our technological problems by the import of skills and the import of sophisticated hardware. There are certain points in the economy which must be held if we are to retain engineering skills of the highest order.

The Government has decided that the computer industry is one such point. It has declared its intention to support a rapid increase in the use of computers and computer techniques and a flourishing British computer industry. To give effect to this policy a programme of action has been drawn up on a wide front. It includes:

(a) the creation of a Computer Advisory Service to bring realistic information about computer capabilities to interested parties in the public sector and beyond;

(b) a programme of support for research and development through the National Research Development Corporation and in government laboratories;

(c) a new round of computers for universities and Research Councils;

(d) a National Computing Centre to promote the joint study of computer programmes for industry and commerce and for research into software for these programmes, and to provide an additional source of training for programmers and system analysts;

(e) arrangements to co-ordinate government computer needs and to project the pattern well into future years so providing helpful information to the industry.

(*vii*) *The Machine Tool Industry*

The machine tool industry occupies a highly significant place in modernization of the economy, because it produces most of the tools of the engineering industry. For this and other reasons the industry has long been the subject of close attention. Certainly no industry has a greater literature of reports, except perhaps cotton.

Earlier this year, the Machine Tool Economic Development Committee, under the chairmanship of Sir Steuart Mitchell, produced the latest of these reports. It contained a wide range of proposals for action, partly on the part of industry and partly to be undertaken by the Government. The Minister, in a statement in the summer, assumed responsibility for most of the recommendations affecting the Government and a fairly widely ranging programme of action is in hand, the elements of which include:

(a) a substantial increase in the research and development effort;
(b) ordering by the Government of pre-production models to prime the pump for new designs;
(c) a special programme on the part of the National Engineering Laboratory;
(d) a new study of the cyclical pattern of the trade with an eye to producing possible remedies;
(e) a review of the machine tool holdings of the government establishments with a view to modernization where appropriate;
(f) action with the universities to stimulate the flow of graduate engineers.

The machine tool industry is one of many industries with important structural problems. It is for the industry itself to take the lead in this matter. It does, however, remain a matter of close interest to the Ministry.

(*viii*) *Electronics*

Fulfilment of the National Plan requires that the rate of growth of productivity shall accelerate from about 3 per cent. per annum to about 3.4 per cent. and growth of exports from 3 per cent. to 5¼ per cent. per annum. These figures embrace the whole of British industry and they relate to a period during which the labour force is likely to remain sensibly constant. The electronics industry can play a vital part in their attainment because it can provide the control, data handling and transmission equipment and computers which are essential.

In this field we have two basic aims, to help the industry to become stronger and to help it to find new markets, particularly in other manufacturing industries. The output of the electronics industry has, for some years, been growing at a rate of about 8 per cent. per annum. In 1964, output probably exceeded £400m. Exports have also been growing and now represent about 3 per cent. of all manufactured goods and 5 per cent. of all engineering goods. Unfortunately, imports have risen even more

rapidly, and there is an urgent need to find new fields for export. Part of the difficulties may arise from the fact that for over twenty years the electronics industry has been dominated by the needs of defence. Sixty per cent. of research and development has been paid for from defence funds and often the subsequent production has been on a scale too low for economic viability. We believe that one of the most important contributions that we can make to the electronics industry is to assist it to develop production techniques. We intend also to support research and development on components of general importance. A good example of this lies in the new field of integrated circuits which is likely to alter the whole face of electronics.

Our second aim is to encourage the wider use of electronic techniques wherever they can assist the non-electronic industries. This is mainly a matter for individual firms but we can help in various ways. Certain industries, e.g. textile machinery, paper making machinery, food preparation machinery and printing machinery, are particularly important from the export point of view, as well as to the domestic economy, and offer scope for automation. We hope that we can help the electronics firms to identify the most useful projects. We may also be able to help by carrying out the preliminary system studies.

(ix) The National Research Development Corporation

The National Research Development Corporation plays an important part in the Ministry's plans for supporting technological advance. The Corporation was set up by the Development of Inventions Act 1948, with two main functions:

(a) securing, in the public interest, development or exploitation of inventions:

resulting from public research: or from any other source which it considers are not being sufficiently developed or exploited;

(b) acquiring, holding, disposing of and granting rights in connexion with inventions from public research, or where the public interest requires, from other research sources.

The word 'inventions' is not restrictive. It is so construed in the Act that the Corporation has wide discretion about the projects it supports and the manner in which it supports them.

The Corporation is financed by advances from the Ministry of Technology; the present limit on outstanding advances (extended by the Development of Inventions Act 1965) is £25m. The Corporation is required 'so far as can be done consistently with . . . (its) purposes' to so operate as to secure as soon as possible that its income cover its outgoings taking one year with another.

The Board of the Corporation is a mixture of full-time executives and part-time members from industry, finance and academic life.

The 1965 Act provided that government departments, with the agreement of the Ministry of Technology and of the Treasury, may ask the Corporation to undertake projects on their behalf and at their expense. In such cases, the tests of public interest are applied by the government department, though the Corporation still has the right to refuse to take on such a project.

The Minister has powers of general direction to N.R.D.C. and ministerial approval is required for certain types of activities; fortuitously these include those on which nowadays N.R.D.C. spends the bulk of its money. But it is clear from the circumstances in which these provisions were inserted in the original Bill that they were primarily aimed at cases where N.R.D.C.'s operations might appear to compete with those of private enterprise, and were not intended to give ministerial control over the Corporation's operations either in general or, for example, where they are particularly costly. Indeed during the passage of the original Bill through Parliament, Ministers were at pains to emphasize the intention that N.R.D.C. should be independent of government control over its day-to-day operations, which were to be conducted on a commercial basis.

The Hovercraft and the computer industry are two prominent examples of N.R.D.C.'s interests.

(*x*) *Standards*

The adequacy of British standards is an important factor affecting our economic progress. Standards become out of date. Some standards are purely British and are damaging to our export trade because they are unacceptable to foreign customers. The Whitworth and B.A. screw-threads are examples.

International standards are growing. Our great dependence on international trade requires that we should wherever possible align our standards internationally. Perhaps our greatest difficulty here is our continuing use of Imperial units. Already, more than half our trade is with metric countries and over 80 per cent. of the world's population are using metric units.

Industry is demanding ever-increasing accuracy. Space technology, micro-wave communication and navigational equipment for aircraft alike demand unprecedented accuracies. Industrial automation is making similar demands. There is increasing pressure on the National Physical Laboratory not only for higher accuracy of the traditional standards but also for entirely new national standards. For example, there are requirements for measurements of very high radio-frequencies and of radiation energy.

Standards are also required for performance. Any strategy for the modernization of industry must include not only pioneering activity to produce new products, but also means for rejecting products that are not

up to standard. This is a task for manufacturers, but the Research Associations and Government Research Stations are already giving much assistance with evaluation and can do more in the future where it is needed by industry.

The use of standards in government procurement is an essential part of the process of aligning British standards internationally, of the advance to metrication and the production of better standards, more particularly performance standards for quality, reliability and fitness for purpose. The Ministry of Technology is therefore taking the initiative in promoting the use of international and metric standards in procurement in the public sector.

The Ministry of Technology is active across the entire standards front, the significance of which to modernization is profound, even though it is not conspicuous.

(*xi*) *Government Procurement*

The prospectus for the Ministry of Technology stated that it would interest itself in considering how arrangements for procurement financed by public funds could be used to assist the aim of promoting technological advance. Much work has been done on this subject and there have been many discussions with industry. The overall figure for procurement in the public sector is about £6,000m. annually and the prospect of using even a small proportion of this to promote technological advance is an attractive one. Some of it is so used already – for example, development contracts in both the defence and civil fields. But when one tries to get to grips with the problem of orientating some of the Government's day-to-day purchasing in directions which will stimulate technology, one faces the immense complexity and wide variety in the pattern of procurement; and if the normal criterion for government procurement of the lowest tender is to be discarded, we must clearly try and find an alternative which is no less clear cut and objective. This will not be easy.

Our examination so far suggests that dramatic changes of purchasing policy on a broad front may be less immediately effective than attacks on narrow, specific fronts, such as computers, and removing apparent anomalies and anti-progressive practices from the system. However, we are not losing sight of the wider problem. Sir Denning Pearson, in the lecture to which I have referred, strongly urged that government procurement should be used as a weapon to support government policy and we have had advice in the same sense from the Confederation of British Industry. Sir Denning suggested a series of government co-ordinating agencies similar to the purchasing committees used by large firms to co-ordinate the purchases of their separate divisions.

This approach would not be over-popular with my colleagues in the large purchasing departments. Nevertheless, we shall continue to watch this wider aspect of the problem and propose changes as and when we can.

(*xii*) *Development Contracts*

Development or research contracts with universities or with industry constitute an effective method of securing technological advance. It has been employed over the years not only by D.S.I.R. in the civil field but also, and on a very large scale, by the defence departments. The Ministry of Technology has inherited D.S.I.R. activities in this field and there have been a number of new and interesting developments. The hope has often been expressed that it will be possible to carry into the civil sphere development contracts on the scale, and with the scope, achieved in defence. It must be remembered, however, that in the defence field the Government's basic purpose is to develop the hardware it needs and which it cannot buy off the shelf. In other words, the Government's purchases dominate the market. This is usually not the case when we are dealing with civil technology.

I add to my list of weapons two which are only indirectly of concern to the Ministry of Technology but which are of overwhelming importance.

(*xiii*) *Economic Environment*

Unless the economic environment is favourable, in the sense that technological innovation pays off, the rules of the game will operate against us. Recently, in a brief visit to the United States, I had a good look at the Massachusetts Institute of Technology. Nothing impressed me more than the fact that within ten miles of the campus there is a ring of new industries all developed over the last ten years and springing directly from technologies fashioned in the Institute. Here, and at various other points in the United States, has been created an environment intensely favourable to new science-based industries. Such industries, of course, exist in this country but I wish I could point with equal conviction to a British university with the same intensely marked periphery of new development. A further point which impressed me is that 50 per cent. of all the courses given at the Institute were not given ten years ago. These are matters worthy of the closest study.

(*xiv*) *Education*

Technological innovation is achieved by men (all too seldom by women) and men are the product of our educational system. Problems arise as to whether the system is meeting the needs of industry. There is much evidence that it is not. For example, we certainly have far too few qualified engineers in industry. This is connected with the schoolboys' conception of engineering as a career, a conception which recent studies[7] have shown to be a disturbing one. It is also connected with the treatment that engineers receive in industry and the extent to which they penetrate higher management. It is connected again with the length and quality of the training

which engineers receive at the university. Questions also arise not only of post-graduate training but also of post-experience training – bringing engineers back to universities to teach them the latest tricks of the trade.

The inter-face between the world of engineering and the world of education is already one of crucial importance and so forms a subject of special interest to the Ministry of Technology.

I wish I had time to discuss our various activities in this field but the subject is too big. Indeed, it is wide enough for a lecture itself. Of course, it covers the waterfront so far as Whitehall is concerned affecting, for example, the Treasury, the Ministry of Labour, the Department of Education and Science and the University Grants Committee. We cover part of our interest through a Committee under Sir Willis Jackson on Manpower Resources for Science and Technology which we sponsor jointly with the Department of Education and Science. We also have a Working Party to study and initiate action on the vital field of the place of the engineer in our society. Its activities include a commission to the Tavistock Institute to study the social aspects of this problem.

ORGANIZATION

Finally, I would like to say a word about our headquarters organization as this presents some features which may interest the Institute. It is always difficult to staff a new Ministry and never more so than on the morrow of a General Election in competition with a wide variety of other new initiatives. We have certainly had our difficulties on this score. Another difficulty arose from the fact that the resources of D.S.I.R. connected with industrial research did not come fully into our possession until nearly six months after the Ministry was formed.

We always intended to form a mixed organization – that is to say, one in which administrators, engineers and scientists were mixed appropriately throughout the organization. In the early days this was not possible as we had to use our inadequate staff to do a vast variety of jobs. But we managed to form a mixed Computer Division on 1 October 1965, and we are now turning the whole organization over to the new pattern.

We now have about a dozen divisions dealing with our various activities, mostly containing a mixture of scientists, engineers and administrators – reporting to a mixed hierarchy. Everyone seems to like the organization though I cannot yet say how successful it will prove. If it succeeds, it will be something of an advance in the history of organization technique.

I am happy to think that we include among our members two of the most distinguished scientists in the land.

Technology cannot be compressed within rigid frontiers. It flows through the activities of every department in Whitehall and outside. In consequence the Ministry of Technology has had to create working

relations with many other departments. This does not ease our task, though the difficulties are often exaggerated. I do not see how the frontier problem can be eliminated altogether without creating a vast monolithic department of the character on which I have touched earlier.

A New Principle

I conclude this section of my remarks by putting before you a principle which I have postulated after studying this subject for some time. I describe it as the principle of maximum purity. You are all familiar with such principles in physics as the principle of least action, the principle of least time and the principle of entropy. My principle is the principle of maximum purity and I have defined it as follows:

> 'Any organization with freedom to study both pure and applied science will, in the absence of external restraints, so conduct its affairs that sooner or later pure science will dominate.'

Time does not allow me to develop the theory behind this principle. However, I offer the following examples of the principle in action:

(a) *The Nobel Prize.* Under Alfred Nobel's will the Nobel Prize could be given for improvements and inventions as well as for pure science. (In 1912 the Academy of Sciences awarded the Nobel Prize for Physics to the Swedish inventor Gustaf Dalen for improvements in navigation buoys and beacons.)

(b) *The Royal Society of London*, where the words 'useful arts' figure in its charter but not conspicuously in its thoughts, at any rate until recently.

(c) *The National Physical Laboratory*, which was dedicated to applied science, but which over the years has become more and more interested in pure science.

(d) *The Universities*, with whom rested responsibility for teaching applied science and which have given an increasingly 'pure' twist to the subject.

Of course, applied science can only flourish in the company of pure science. But the principle of maximum purity has to be watched to make certain that it does not get things all its own way.

REFLECTIONS

So I come to the end of my brief account of the Ministry of Technology. You may perhaps remark that according to this account, it has all been going on for sixty years and that I have said nothing that D.S.I.R. could not have said a couple of years ago. This would not be true. The Ministry of Technology has brought a new emphasis and a new orientation. It has brought into existence a point in government, under a Minister of Cabinet

rank, where the technological problems of industry are discussed in a scientific environment. The National Plan calls for a 40 per cent. expansion by 1970 in the output of the mechanical and electrical industries and a 52 per cent. increase in their exports. It is with these industries that the Ministry of Technology is mainly concerned. Our task is to determine the points at which government aid is required to improve technological efficiency and to take action accordingly.

The Ministry has had a warm welcome from industry which has helped us in many ways. The presence on the Minister's Advisory Council of such men as George Nelson, Hugh Tett and Frank Kearton is one example of this help.

My final thought is this. The secret of survival is adaptability to change. Over the years Britain has been ready to respond to change. The events of 1900 and 1915 are recent examples of this. Today, the need for adaptability is greater than ever. The secrets of science are being laid bare at a rate unimaginably greater than at any point in history. Three-quarters of man's knowledge is the achievements of men still living. Our commercial and technological environment is changing fast. We must change too or face the consequences. The Government has a part to play – just as it had sixty years ago. It is more than ever critical today. The Ministry of Technology has been criticized as too slow. This is fair comment. One reason can be found in the immense complexity of our task. But it is right to persevere and I have been glad of this opportunity to talk about our work.

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